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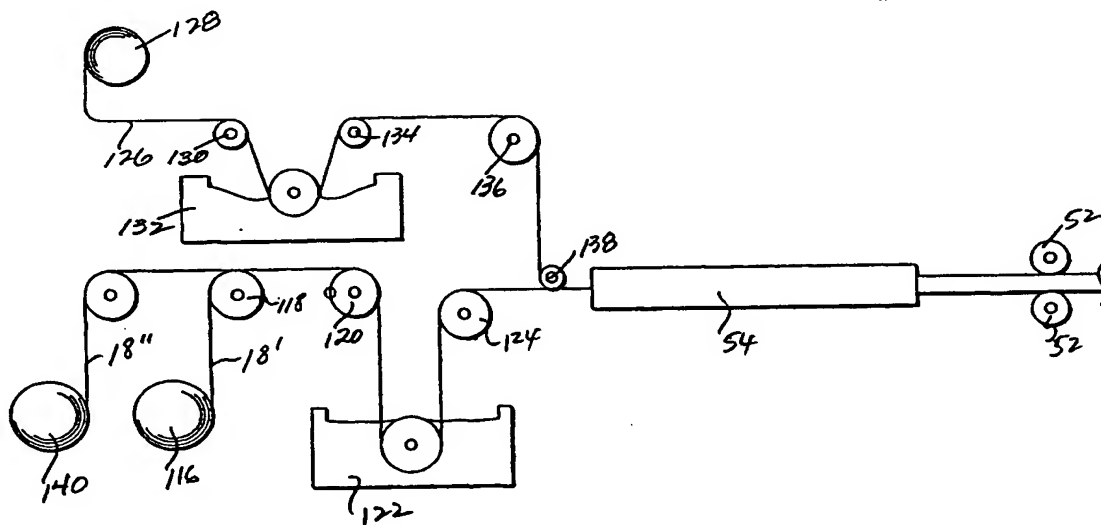
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(54) Title: **PULTRUDED PART AND METHOD OF PREPARING A REINFORCEMENT MAT FOR THE PART**



(57) Abstract: A method of pultrusion includes collating an assembly of substantially longitudinally continuous fibrous elements (126, 18', 18'') and a resin from a bath (132, 122), pulling the elements (126, 18', 18'') and the resin through a die (54) to shape the elements and to effect setting of the resin, where one of the elements is a mat (18a) specially designed to transport primarily transverse fibers (32) into the part (10). The mat has a first layer (34) containing a plurality of glass fibers (32) which extend substantially transversely of the mat (18a) so as to be arranged in the part (10) to provide strength to the part (10) primarily in the transverse direction.

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PULTRUDED PART AND METHOD OF
PREPARING A REINFORCEMENT MAT FOR THE PART

5 Background of the Invention1. Field of the Invention

This invention relates to a method of forming a pultruded part and especially to a process of preparing a mat for use as reinforcement for the resin composition used in pultrusion of the part. In particular, the invention concerns an improved reinforcement mat made up of a number of layers, including
10 a layer having fibers which extend transversely of the mat, fibers that are oriented longitudinally of the mat, fibers that are arranged obliquely of the longitudinal and transverse fibers, entangling fibers that extend into the other fiber layers, and a binding resin for the fibers.

The invention is especially useful for pultrusion of parts for fenestration products and relates to a reinforcement mat for the pultrusion resin. Representative fenestration products in this respect include
15 items such as pultruded window jambs, sills, heads, sash stiles or sash rails.

2. Description of the Prior Art

Pultrusion is a known technique in which longitudinally continuous fibrous elements, which can include roving and/or a mat, are combined into a structure. The process generally involves the pulling of
20 the rovings and mats through a resin bath, and into a heated forming die. The heat of the die cures the resin, and the part is pulled through the die, on a continuous basis. The mat and roving are textile-type products, as they are flexible and conformable. Current pultruded parts are generally 1/4" or thinner, and in the fenestration industry, range from 0.07" - 0.1" thick. The pultruded parts are solid structures, and generally have a profile such as a box, or open section, where the bends in the thin-profile give the
25 pultrusion a high-degree of rigidity and structural integrity.

Mat and roving composite reinforcements are primarily glass products, while the resin matrix is usually, but not necessarily, a thermosetting polyester. Mat material is generally in the form of a non-woven mat, where glass fibers are randomly placed in a planar swirl pattern, resulting in a felt-like web.

Before pultrusion, glass rovings are groupings of up to thousands of microns-diameter glass fibers,
30 that mechanically behave like flexible rope, because the diameter of each filament is so small, even though it is made of glass, commonly considered to be a rigid material. After pultrusion, the glass rovings are held together by the matrix resin, resulting in the rigidity of the pultrusion composite parts. In a pultrusion profile, the mat and roving constitute the reinforcement, while the resin constitutes the matrix of the solid composite.

35 The technique of pultrusion has been used for many years for manufacturing various parts including simple parts such as rods and more recently including parts of more complex and thinner cross-

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section. One requirement for thinner parts is that of providing fibers in the construction which are transverse to the length of the part to provide transverse strength.

The longitudinal strength of pultruded parts is very high since the majority of the fibers extend longitudinally in the form of a series of longitudinally extending rovings pulled through the die. However
5 the transverse strength of pultruded parts is generally compromised because only a limited number of the fibers extend transversely.

Mats having transverse fibers and placed on opposite sides of the outside of a pultruded part have been tried in the past. Various types of mat materials are available but the mat material which is principally used is one in which the fibers are laid in random patterns in a flat layer and the fibers then held together by
10 a binder which acts to attach crossing fibers at the junctions to form a two dimensional structure. This type of mat has high shear resistance due to the large number of interconnections between the randomly oriented fibers. However the main intention of the mat is to provide a high proportion of the fibers extending in the transverse direction and this is not achieved since the fibers extend in random directions. Therefore, only a very small proportion of the total fiber component extends in the transverse direction.

15 It has long been recognized that the absence of a suitable mat has significantly reduced the quality of pultrusions particularly in regard to the transverse strength, thus leading to limited penetration of pultruded parts into various marketplaces.

The conventional mat has also a number of serious problems which interfere with the efficiencies and economics of the pultrusion process.

20 First, the mat is a relatively expensive, and there is waste of offal when the mat is slit to width.

Second, the mat is difficult to form into the required complex shapes. Thick, strong mats are available but they are more difficult to bend and shape, before entering the die. Lightweight mats are easier to shape, but they lack transverse strength, and are more prone to ripping-out at the die entrance.

The choice of mat is therefore a compromise between the necessity for bending to shape and the
25 required strength of the pultruded part.

More recently, mats have become available that are needled in a direction at right angles to the plane of the mat, to provide loops that cooperate with the rovings, and also form a mat structure which has greater bond strength in the through-thickness direction, to provide necessary pull strength. This mat has a tendency to stretch, and is very expensive, thus interfering with the economics of the pultrusion process.

30 Available reinforcing mats use continuous fibers rather than cut-staple fibers in order to provide the highest strength of the fibers. However, the needling tends to break at least some of the pulled glass fibers in order to effect their distortion from the plane of the mat, thus reducing the strength of the broken fibers.

United States Patent 4,058,581 (Park) discloses an attempt to attach discontinuous fibers to
35 longitudinally continuous fibers by simply adding these into the bath of resin so that they may be picked up by the longitudinal fibers as they pass through the resin. There is no assertion by the supplier that this leads

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to a layer of transverse fibers in the part wall and it is believed that any fibers so attached would simply be pulled straight and longitudinal by passage through the die.

United States Patent 5,324,377 (Davies, one of the inventors herein) discloses a technique to add fibers transverse to the length of the part by extruding those fibers into the outside of the part so that they
5 are carried with the part through the die. Unfortunately this technique has not yet led to significant success so that the requirement for an improved mat has remained largely unfulfilled.

In order for the reinforcing mat to pass through the die with the longitudinal fibers, it is necessary for the mat to have a sufficient longitudinal strength that it does not tear as it is pulled through the die. Furthermore the mat must have a sufficient shear strength so that it does not twist or skew allowing one
10 side edge of the mat to move in advance of the other side edge. If such twisting or skewing occurs, the mat will become distorted in the part and the mat eventually will break down if the distortion goes beyond a certain level thus bringing down the process and requiring a re-start.

The term "shear strength" used herein therefore relates to the resistance of the mat to twisting or skewing in the plane of the mat in a direction such that one edge of the mat moves in advance of the other
15 edge of the mat.

Summary Of The Invention

It is an important object to provide an improved pultruded product, and especially to provide an improved method of preparing a reinforcement mat for the resin pultrusion composition in which the mat
20 has high strength to weight characteristics, is flexible for utilization in pultruded parts of complex and varied shape, is economical to manufacture, and that can be used in standard pultrusion processes without significant modification of those procedures.

It is an object of this invention to provide an improvement in the technique of pultrusion by providing an improved mat construction which give increased transverse strength for a particular thickness
25 of mat and resin material content.

A further object of this invention is to provide a method of preparing a mat for use as reinforcement of a resin composition used in forming an elongated pultruded part in which the mat has a pull layer made up of continuous, generally longitudinally-arranged pulling fibers which impart added strength to the mat longitudinally thereof in the pull direction. A reinforcement layer of angular mat fibers
30 is provided in association with the longitudinal pull direction of the mat to provide stiffness to the mat. A fibrous batting is provided in association with the pull and reinforcement layers in which at least certain of the fibers of the batting extend through the thickness of the mat layers and interconnect the fibers of the layers to increase the integrity of the mat, especially in a traverse direction. A synthetic resin binder is provided which becomes sufficiently fluid during pultrusion and heating of the part to diffuse through the
35 layers of the mat and provide an interconnection therebetween upon cooling of the binder.

Also an object of the invention is to provide a method of preparing a mat for use in reinforcing a pultrusion resin in which the lay-up of mat layers including the fibrous batting layer is subjected to water-jets from hydro-entangling apparatus or from a series of barbed needles directed into the layered mat, both of which function to deflect the fibers of the batting layer to produce entangling fibers that extend through the thickness of the mat layers and interconnect the fibers of the layers, thus increasing the integrity of the mat during pultrusion of the part.

Preferably, the longitudinally-extending fibers as well as the transverse and oblique fibers of the mat are glass fibers. However, the entangling fibers extending from the batting desirably have a bending resistance less than that of the glass fibers. To this end, the batting is preferably of a cut-staple, synthetic resin material such as a polyester. These fibers therefore can also be used to form the conventionally used veil to keep the glass away from a finished surface of the pultruded product.

Another object of the invention is to provide a method of preparing a mat for reinforcing a resin composition used in pultrusion of a part wherein the longitudinal and transverse layers are interconnected by stitching utilizing equipment for that purpose that is generally available and has long been used in the textile industry.

An object of the invention is to provide a method of preparing a mat for reinforcing a resin composition used in pultrusion of a part wherein a series of holes are formed in the mat layers which extend through the thickness of the mat layers and receive binding resin therein for increasing the binding effect of the resin upon hardening of the latter.

Also an object of the invention is to provide a method of preparing a mat for reinforcing a resin composition used in pultrusion of a part wherein the reinforcing mat for the pultrusion resin is fabricated as a unitary body of indefinite length but which may be readily cut widthwise thereof to any desired width to fit a particular pultruded part.

In accordance with the method of preparing a mat for use as reinforcement of a resin composition to be used in forming an elongated pultruded art, in a preferred process, elongated mat layers are placed side-by-side on a supporting surface to present a layer having fibers extending longitudinally of the mat. A mat layer having shorter fibers is brought into association with the elongated mat layers in orientation such that the fibers extend transversely of the mat at an angle of about 90° with respect to the elongated mat fibers. Mat layers are also incorporated in the mat body having oblique fibers which extend at an angle of about $\pm 45^\circ$ with respect to the longitudinal length of the elongated fibers. Thus, the fibers of the oblique fiber layer are positioned such that certain of the fibers are located at an oblique angle of about 45° with respect to the longitudinal length of elongated fibers. Other fibers of the oblique fiber layer are located at an angle with respect to the longitudinal length of the elongated fibers in a direction opposite the angularity of the fibers of the first oblique fiber layer referred to above. Use of oblique fibers, one-half of which extend diagonally from one side of the mat to the other, while the other half extend diagonally to the other side of the mat, provide shear stiffness along both sides of the mat.

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Desirably, a relatively thin polyester batting layer is brought into association with the longitudinally extending fibers, those at 90° with respect to the longitudinally extending fibers, and the oblique fibers. Hydro-entangling equipment, or a series of relatively closely-packed, barbed penetration needles are employed, to deflect at least certain of the fibers of the batting layer into and through the other layers to interconnect the fibers of the various layers and increase the integrity of the layers of the mat in its final completed form.

A synthetic resin binder may be added as described to the layer of reinforcement fibers which is capable of becoming fluid at the temperature realized in the pultrusion die so that the resin will diffuse throughout the extent of the fibers for binding the fibers together upon cooling and solidification of the binder. Alternatively, certain or all of the fibers may be provided with a synthetic, powder, solvent, thermal or aqueous-based thermoplastic binder sheath which is capable of changing to a sufficiently low viscosity at the temperature within the pultrusion die that it will spread throughout the thickness of the mat, either as a supplement to the added resin binder, or in lieu thereof.

Provision of the reinforcement fibers which extend transversely of the mat at substantially a 90° angle with respect to the pull direction of the mat enhances the reinforcing effect of such fibers in that there is little or no wasted forces in other directions. Although transverse fibers oriented at a 90° angle are preferred, other angularities within the range of 60° to 90° may be accommodated with satisfactory anti-skewing properties, especially if fibers are provided which are disposed in offsetting, opposite angular directions.

Brief Description Of The Drawings

The invention will now be described in conjunction with the accompanying drawings in which:

Figure 1 is a schematic, cross-sectional view through a typical finished pultruded fenestration part;

Fig. 1A is an enlarged, fragmentary detail of a portion of the fenestration component shown in Fig. 1 as outlined by the circular bullet;

Fig. 2 is a further enlarged, fragmentary, essentially schematic detail of a part of the fenestration component as shown in Figs. 1 and 1A;

Fig. 3 is a schematic flow diagram of a pultrusion process and the equipment employed for carrying out the present invention;

Fig. 4 is a schematic, greatly enlarged, fragmentary plan view of a preferred embodiment of a mat prepared in accordance with this invention and useful for reinforcing the resin composition utilized to pultrude a product of the type illustrated in Fig. 1;

Fig. 5 is a fragmentary, cross-sectional view taken substantially along the line 5-5 of Fig. 4;

Fig. 6 is a fragmentary, cross-sectional view taken substantially along the line 6-6 of Fig. 4;

Fig. 7 is a schematic representation of apparatus for fabricating a mat in accordance with this invention;

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Fig. 8 is an enlarged, schematic depiction of a hydro-entangler identified as a water-jet and forming a part of the apparatus shown in Fig. 7;

Fig. 9 is a fragmentary, greatly enlarged, plan view of an alternative embodiment of a mat prepared in accordance with this invention and useful for reinforcing the resin composition utilized to pultrude a product of the type illustrated in Fig. 1;

Fig. 10 is a fragmentary, cross-sectional view along the line 10-10 of Fig. 9;

Fig. 11 is a fragmentary, cross-sectional view along the line 11-11 of Fig. 9;

Fig. 12 is a fragmentary, greatly enlarged, cross-sectional view of a further embodiment of a reinforcing mat in accordance with this invention;

Fig. 13 is a fragmentary, greatly enlarged, cross-sectional view of another embodiment of a reinforcing mat in accordance with this invention;

Fig. 15 is an enlarged, fragmentary, schematic representation of needle apparatus as an alternative for forming a series of holes through the thickness of the mat; and

Fig. 16 is an enlarged, fragmentary view of a representative needle useful in the apparatus of Fig. 7.

In the drawings like characters of reference indicate corresponding parts in the different figures.

DETAILED DESCRIPTION

A typical fenestration product which for example may comprise a pultruded part 10 in the form of a window sash rail is shown Fig. 1. It can be seen from this figure that the cross-sectional shape of a part 10 of a fenestration product is of fairly complex configuration which typically has heretofore been difficult to fabricate on a uniform, cost-effective basis because of the inability to reinforce the pultrusion resin with an effective reinforcement material. Part 10 as shown comprises a hollow, closed, pultruded body 12 having uniformly spaced outer wall structure 14 and inner wall structure 16. As schematically shown in Fig. 2, wall structures 14 and 16 each include a reinforcement mat 18 on opposite sides of the central resin body 20 having longitudinally-extending glass reinforcing roving 22 therein. A mat is generally applied on the inside and the outside surfaces of a complex shape, as for example illustrated in Fig. 1. The mat applied to the inside and outside surfaces of the part offers a skin to the pultrusion. The skin serves to give the pultrusion wall transverse strength, by delivering transverse oriented glass rovings to the exterior of the laminate. Longitudinally extending rovings function to give the pultruded part longitudinal strength and modulus.

In most cases, it is necessary to provide symmetry of the mat layers to allow the assembly of fibers to pass through the die. One simple example of the shape is shown in Fig. 1 but it will be appreciated that the shape will vary in accordance with requirements and the shape shown is merely intended to be representative of shapes suitable for various end uses. Simple shapes such as rods in most cases do not need the transverse strength of the mat, whereas more complex shapes such as those used for fenestration

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profiles always use mat on the inside and outside. A relatively thin layer 24 of the resin making up body 20 covers the outer face of each of the reinforcement mats 18.

In Figs. 4, 5 and 6, a preferred embodiment 18a of the mat 18 is schematically illustrated in plan view and cross-section, respectively. Mat 18a includes a series of layers of glass fibers 26 which are shown schematically as separate, transversely-spaced, elongated rovings 28 defining a pull layer 30 made up of a large number of relatively fine glass fibers extending longitudinally in the pull direction of mat 18a in what may be characterized as the 0° direction. These rovings should be in the range of $0^\circ \pm 20^\circ$ with respect to the longitudinal length of the mat.

A second set of spaced glass fiber rovings 32 defining a reinforcement layer 34 all extend at an angle of about 90° transversely of mat 18a with respect to the longitudinal axes of rovings 28 making up pull layer 30. The fibers are formed by rovings which extend continuously across the width of the mat 18a and are not cut-staple fibers. Thus, the fibers of the reinforcement layer 34 are substantially wholly laid directly across the width of mat 18a and are defined by rovings laid side-by-side. The 90° orientation of the fibers in transverse rovings 28 maximizes the transverse strength/modulus of the pultruded part 10, thus reducing the amount of fibers that must be provided transversely of the mat 18a. Rovings 32 are desirably positioned in substantially directly side-by-side, slightly spaced relationship to form a blanket of fibers without substantial breaks therebetween. In lieu of the preferred 90° orientation of rovings 32, the rovings may be positioned at other angularities within the range of about 60° up to 90° on the plane of the mat.

Desirably, the individual rovings 32 are substantially larger in cross-sectional size than the cross-sectional dimension of each of the elongated rovings 28, as is evident from the schematic representations of Figs. 5 and 6. The transverse reinforcement fibers making up rovings 32 constitute an amount in the range of about 50% to about 90% of the total fiber content in the mat 18a.

An angular roving layer 36 is located outside of layer 30 and comprises a plurality of spaced glass fiber rovings 38 located at an angle of 45° with respect to rovings 28 of reinforcing layer 30. Again, the rovings 38 are of substantially less cross-sectional thickness as compared with the cross-sectional thickness of transverse glass rovings 32.

Another angular roving layer 40 made up of a series of spaced glass fiber rovings 42 is located on the side of transverse layer 34 away from layer 30. The glass fiber rovings 42 are desirably at angle of 45° with respect to rovings 28, but in this instance are oriented oppositely of the orientation of rovings 38. Thus, angularity of rovings 38 may be characterized as $+45^\circ$ while the angularity of rovings 42 may be characterized as -45° with respect to the longitudinal axes of rovings 28 of layer 30.

The rovings 38 of layer 36 and rovings 40 of layer 42, extending in opposite directions at 45° angles with respect to rovings 32 of layer 34 extend symmetrically across the width of mat 18a between opposed edges 43 and 45 imparting preferred shear strength to the mat 18a. This increased shear strength is attributable to the fact that rovings 38 of layer 36 and rovings 42 of layer 40 transmit forces substantially equally in the opposite directions to the edge portions 43 and 45 of the mat. By providing such diagonally

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and oppositely oriented fibers at $+45^\circ$ and -45° , there is little tendency for one of the edge portions 43 or 45 to move in advance of the other edge and thus generate a twisting or skewing action which could not be accommodated during pultrusion of part 10. Again, the oblique or diagonal rovings 38 and 42 are continuous and straight across the width of the mat so as to maximize transmission of forces in respective diagonal directions. Alternatively, the rovings may be positioned transversely of the mat in opposite directions within the range of about 30° to about 90° .

Layers 30 and 34 give the mat 18a dimensional stability in the 0° and 45° directions so that the mat 18a can be preformed to shape, yet offer sufficient tracking consistency and necking-resistance for consistent processing during pultrusion. A polyester entanglement batting layer 44 is shown as being located against the outer face of angular roving layer 36, although the batting layer 44 may if desired be placed against the outer face of angular roving layer 40. The batting layer 44 has a series of relatively short fibers 46 randomly oriented in the batting and at least certain of which are intertwined or entangled throughout all three dimensions of the batting. As is most evident from Fig. 6, and as will be explained in greater detail hereinafter, a proportion of the fibers 46 are deflected from the plane of batting 44 and extend as entanglement fibers 48 through the layers 36, 30, 34 and 40 respectively, entangling and interconnecting glass fibers of glass rovings 38 of layer 36, rovings 28 of layer 30, rovings 32 of layer 34, and rovings 42 of layer 40, as illustrated for example schematically in Fig. 6.

The entangling fibers 48 which carry substantially through the thickness of mat 18a function to integrate the layered structure of the mat and prevent the layers from separating or moving relatively one with respect to another as the reinforcement mat is pulled through the pultrusion die, thus providing required temporary longitudinal, transverse and diagonal strength and twisting resistance during the pultrusion process.

The reinforcement mat 18a is made in multiple process steps, beginning with the arrangement of glass rovings 32 in the transverse direction, making up reinforcement layer 34, including the arrangement of the rovings making up angular roving layer 36 and angular roving layer 40, placement of entanglement batting layer 44 against at least one face of the layered composite, which after entanglement serves to hold the mat 18a together during the pultrusion process steps, the consolidation of the fibers, the addition of a binder, and the arrangement and size of holes through the mat 18a.

Rovings 32 of reinforcement layer 34 and made up of glass fiber bundles are festooned in the transverse direction (90° with respect to the pull direction of the part 10), generally 2-32 courses per inch to form a web (broadgood). Bundles of glass rovings 28 of less bulk than rovings 32 and comprising the pull layer 30 are laid on at least the top, and optionally on the bottom, of the transverse reinforcement layer 34, in the 0° direction of pull. Smaller reinforcement bundles of glass fibers 38 and 42 are laid in the $+45^\circ$ and -45° directions on opposite sides of pull layer 30 and reinforcement layer 34, as shown schematically in Figs. 5 and 6.

All of these glass fiber layers (90° , 0° , $\pm 45^\circ$) are preferably combined into a web by stitching with polyester thread using a conventional multi-head stitching machine used in the textile industry, or by thermoplastic consolidation with resins. In the latter case, the resin may be supplied, or supplemented with a thermoplastic resin sheathing on certain or all of the glass fibers of the rovings.

5 The batting 44 is preferably a relatively thin web of polyester staple fibers laid down by a conventional air machine. These polyester staple fibers are blended and carded, and a predetermined thickness is achieved by stacking of a plurality of staple-fiber webs. The polyester batting in the form of a web is laid on top of the angular layer 36, or in the alternative, over angular layer 45, or as a further alternative, over both of the layers an 36 and 40.

10 The batting layer 44 is hydro-entangled with the angular layers 36 and 40, pull layer 30, and transverse reinforcement layer 34 by way of multiple banks of water-jets, that wet the randomly-oriented fibers of the polyester batting web 44 directly to the glass web layers 36, 40, 34, and 30, and force certain of the polyester fibers into locations extending throughout the mat 18a. As shown for example in Figs. 6, 12 and 14, the hydro-entangled fibers act as between-glass bundle spanners, and within-glass bundle
15 spanners, resulting in a somewhat flexible, and continuous mat product. This mat product is calendered to reduce loft, needled to increase permeability, and padded with a PVA or similar binder material, to increase stiffness, and increase the dry-mat stiffness. The calendering, needling, and padding steps can be rearranged, processed multiple times, or omitted if the glass layers are thermally bonded with a resin as explained in detail hereinafter, depending on the desired permeability, stiffness, and thickness required for
20 the mat, to optimize the pultrusion process, and the mechanical properties of the pultruded fenestration product, such as a window frame sill.

 The fiberglass for the 90° glass fibers of roving 32 is preferably a 900 yield E-glass roving that has been treated with an organo-silane sizing composition to increase reinforcement-matrix interfacial strength. The $\pm 45^\circ$ oriented glass fibers 38 and 42 and the 0° direction glass fibers 32 are G150's (15000
25 yards per pound) with a thermoplastic resin sheathing as recommended and supplied by Engineered Yarns Incorporated of Fall River, MA. The polyester material making up batting web 44 preferably consists of a blend a 60% Welman 1.5 denier x 1.5 " polyester staple fiber, and a 40% Kosa 1.5 denier by 1.5" long bicomponent fiber, crimped and baled. The Kosa fiber gives the batting web 44 a heat-fusible component, while the Welman fiber enhances the consistency of the polyester batting and decreases shrink of the web
30 during heat-fusing.

 After the blend is mixed, an opener filamentizes the fibers. The fibers are then air laid as a web via the Rando process onto the fiber glass substrate. The web is hydro entangled to the fiber glass substrate, dried, calendered to consolidate and reduce loft, needled to improve permeability, and then chemically treated via a padding operation where a PVAc coating is applied to the mat to improve handling
35 properties.

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The preferred material of batting 44 is a polymer such as randomly-oriented, cut-staple polyester fibers in which there are ends of the fibers extending across the width of the mat. The reduced thickness and the cut ends of the polyester mat allow the hydro-entangling jets to grasp the fibers and to carry parts of the fibers across from the plane of the mat into and through the fibrous glass layers to the underlying plate, thus effecting entangling of certain of the fibers of the batting mat with the underlying glass roving layers. The polyester fibers of the batting mat may be grasped by the water-jets at the end of a fiber or at an intermediate location of the fiber. The fibers making up batting 44 should be of characteristics such that the fibers have a relatively low resistance to bending so that fibers may be moved downwardly through hydro-entanglement, or by mechanical structure such as barbed needles or the like. Glass fibers of reduced denier meeting the requisite flexibility requirements may be also used as a batting material for the hydro-entangling layer 44 of mat 18a.

The speed of the reinforcement mat 18a during manufacture of that mat is desirably about 15-25 ft. per minute. A preferred mat width is 20 in., but a wider mat can be fabricated using larger equipment. To create the mat 18a, glass roving supplied as a packaged spool is placed on a creel, and fed onto a set of parallel belts. The glass fibers of roving 32 are wound around needles along each edge of the endless belt, to arrange the glass fibers for the desired orientations. The fibers of longitudinal roving 32 and the fibers making up the roving of angular layers 36 and 40 preferably have been pre-coated with a thermoplastic synthetic resin comprising an amid, a polyester, or a similar reactive resin which will soften and flow at the temperature realized in the die of the pultrusion process. When passed through the pultrusion die, the temperature realized within the die is sufficient to melt the resin and cause the resin to flow and thereby fuse the glass fibers of all of the glass layers of the mat 18a together, thereby producing a windable glass pre-mat. Preferred results have been obtained by using 11 courses per inch of roving 36, making up 90° reinforcement layer 34, about 8 courses per inch of 45° angular, diagonal fibers, and about 8 courses per inch of 0° fibers in an assembled pre-mat for mat 18a.

Meanwhile, the non-woven batting web 44 is made by blending of polyester staple fibers. The staple fibers are blended and opened in a Sigma Fiber Controls non-woven opener. The polyester fibers are then fed through a Rando webber so that a density of approximately 32 gram/square meter is reached. The Rando feed and doff speeds are set at about 2.5 and 1.0 respectively. The polyester non-woven web 44 is then combined with the glass pre-mat as described above.

The glass pre-mat with non-woven polyester web applied is fed into a hydro-entangler 66, as for example shown schematically in Fig. 8, on a fine-mesh belt to supplement jet reflections, to help to entangle the mat 18a. A suitable hydro-entangler is commercially available from ICBT Perfojet of Mont Bonnet, France. In general, the hydro-entangler 66 has upper manifold structure 68 receiving water from supply source 70 provided with a plurality of openings or nozzles 72 which direct water jets 74 directly onto mat 18a. The water-jets delivered from nozzles 72 are preferably pulsed so that the jet streams exit through respective nozzles 72 and pass through the thickness of mat 18a until impacting the upper surface

of a fine mesh belt 76. The water streams impacting against the upper surface of belt 76 cause the water to dissipate and thereby spread the fibers carried by the jet streams transversely across the top of the plate 76 to enhance entanglement of mat 18a.

The ICBT Perfojet hydro-entangler has three horizontally-spaced manifolds of the type shown schematically in Fig. 8, each having a row of water-jet nozzles 68, with the nozzles spaced at approximately eight per inch, providing a total of 100 to 150 nozzle openings. The water is jetted onto the mat 18a with the first manifold set at a water pressure of 500 psig, the second at 500 psig, and the third at 1200 psig. The mat 18a becomes entangled with fibers 48 as the water jets from manifold 66 pass through the layered material making up mat 18a. The mat 18a in web form is directed under a vacuum duct, drawing most of the water from the mat. The mat 18a then passes through a 15-foot diameter drum drying oven, such as one available from National Drying of Cary, NC, and that uses 200°F air forced through the thickness of the mat 18a to dry all of the layers thereof.

In lieu of using a hydro-entangler as described, a head (not illustrated) may be provided which supports a series of barbed needles 142 as shown in Fig. 6. In this case, the batting mat layer 44 should be opposite the points 142a of the needles so that when the barbed needle penetrate the mat, the barbs 142b do not engage the fibers 46 of batting mat layer 44. However, upon retraction of the barbed needles 142, the barbs 142b thereon engage certain of the relatively short fibers 46 and pull all or at least a portion of such fibers upwardly into the glass roving layers to entangle the glass fibers with the polyester batting fibers 46.

The mat 18a is then calendered through smooth 12 in. diameter rolls on a B.F. Perkins calender set at 120°C with a minimum gap of 0.007 in., to reduce the mat thickness, and fuse the polyester material into the glass pre-mat. The calendered mat 18a is rolled, and allowed to cool to ambient temperature.

The entangled mat 18a is then unrolled and fed into a Dilo needler with a needle board using #16 needles spaced six-rows deep. The Dilo needler uses barbless needles to achieve a 10 x 10 holes-per-inch density. The punch depth is 14 mm, take off gear is set at 7, the base gear at 1.75, resulting in a stroke rate of 300 per minute, at a 1 meter/minute advance rate. During needling, the needles are heated to 160° F, by use of electric heat guns placed inside the Dilo needle box area, and blowing air through the length of the needle board.

The mat is next fed into an A. G. Mathis padder to apply a 2:5 solution of Franklin Duracet 600 PVAc, diluted with tap water. The mat picks up this binder, and is then squeezed through the rubber drying rolls set at 30 psi, at the given speed per the needling process. The mat passes through another identical National Drying of Cary, NC, 15-foot diameter drum drying oven that uses 200°F air forced through the thickness to dry the mat.

The mat is then slit longitudinally to the desired width for pultrusion, and fed into the pultrusion machine with resin-saturated glass rovings.

Equipment for pultruding a part 10 using a mat 18 as an outer skin reinforcement on one or both sides of the part is illustrated schematically in Fig. 3. Pulling mechanism 52, which for example may

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comprise roller structure, is operable to pull part 10 from a pultrusion die 54 of the transverse configuration of the part to be produced.

A mat 18' prepared in accordance with this invention as previously described may be directed from a source roll 116 over schematically illustrated roller 118 and 120, thence through resin bath 122, over roller 124 and into the pultrusion die 54. A web 126 of glass roving from source roll 128 passes over roller 130, through resin bath 132, and then over rollers 134, 136 and 138 into the die 54. Mat 18'' is supplied from source roll 140 and across rollers 118 and 120 into bath 122 and across roller 124 into die 54. A conventional pultrusion resin formulation may be used for pultruding part 10 with a typical formula which, for example, may include a mixture of polyester and styrene resins, along with a hardener, a catalyst, a calcium compound filler, a suitable surface modifier, and a die lubricant.

It is understood that the representation in Fig. 3 is schematic only and intended to indicate that mats 18' and 18'' and the longitudinally-extending rovings 126 are located such that mat 18' is one skin layer of the pultruded part, glass rovings 126 are centrally disposed of the part, and mat 18'' is positioned as an opposite skin layer of the part. Furthermore, instead of passing the roving and the batting mat through respective resin baths, as shown schematically in Fig. 3, resin may be applied to the roving and the batting using conventional resin-applying procedures that are well known to those skilled in this art.

An adhesive binding material such as PVA in a water carrier and containing about 20% to about 60% solids, corn starch or other adhesive material well known to one skilled in the art can be used to assist in interconnecting the structure so that the entangled fibers are bonded to the fibers of the layers 30, 34, 36 and 40 and the fibers are bonded to each other. Generally, the binding agent is present in an amount in the range of 2% to 20% by weight (dry weight without water). However, the amount of binding agent is significantly reduced relative to conventional non-woven mats and thus the stiffness of the structure is very much reduced and therefore improved, allowing the reinforcement mat to bend to take up the complex shape of the part to be formed while restricting shear.

If thermoplastic fibers are used for entangling, the binder can be reduced or even omitted and instead the fibers heated to provide some amount of heat bonding to each other and to the glass or main fibers. In the arrangement shown in Fig. 7, some of the entangling fibers are of a high melting point so that they remain intact and thus act as entangling fibers, and some are of a lower melting point so that they act as bonding fibers.

The mat 18 as described provides reinforcement which has sufficient structural strength in the longitudinal and shear directions to ensure that it will be transported through the pultrusion die without significant longitudinal deformation. This is attributable to the fact that the main bulk of the fibers are arranged in the transverse direction to provide the finished product with the required transverse strength. The number of fibers therefore necessary for a predetermined transverse strength is significantly reduced since the bulk of the fibers are arranged in the direction to maximize the strength provided by each fiber.

Referring specifically to Fig. 7, apparatus 78 includes a conveyor belt 80 arranged to carry the components of the mat 18 from an initial supply to a wind-up device 82. The components of the mat 18 are laid onto the belt in required sequence from a supply thereof which includes a plurality of supply units generally indicated by the numeral 84.

5 Diagonal roving supply head 86 functions to lay down glass fiber rovings 42 at an angle with respect to the longitudinal length of belt 60 and preferably at an angle of about 45°. The head 86 traverses back and forth across belt 60 in timed relationship to the speed of the belt 60 to provide diagonally-oriented glass rovings. Glass fiber rovings supply head 88 is operable to reciprocate back and forth across the width of belt 60 to lay down transverse glass fiber rovings 32, again in timed relationship to movement of belt 60, 10 to provide rovings which are at a 90° angle with respect to the path of travel of belt 60. Supply head 90 continuously lays down glass rovings 28 along the longitudinal length of belt 60, thus providing a 0° lay of rovings.

Diagonal roving supply head 92 lays down a glass fiber rovings 38 on the previously-applied rovings, at a 45° angle opposite the angularity of rovings 42. Thus, the rovings 38 may be characterized as 15 + 45° and the rovings 42 characterized as - 45° with respect to the longitudinal length of the rovings laid down on belt 60 and thereby with respect to rovings 28.

The mat structure so formed is passed through a set of hot rolls 98 which act to elevate the temperature of the materials previously laid down on belt 60 so that when glass rovings are used that have a polymer sheath thereon as described above, the polymers decrease sufficiently in viscosity at the operating 20 temperature of the apparatus 78 to flow through and assist in bonding of the layers of the mat one to another upon solidification in the final product. The rolls 98 act also to calender the mat so that it is compressed and slightly reduced in thickness. In some cases the heat may be omitted and simple calendering action be used.

When the glass fiber pre-mat so formed is consolidated by the bonding action, an air lay machine 25 100 receives cut-staple fibers of a suitable polymer such as polyester from a source thereof which may include a proportion of high melt fibers that withstand a temperature of about 350°F, and a remainder of low melt fibers which melt at about 270°F. These fibers are blended and laid by the air lay machine onto the top surface of the mat previously formed. The details, construction and operation of equipment for air laying of staple fibers is well known to those skilled in the applicable art.

30 After the staple fibers are laid onto the mat, the collated structure is passed through the water-jet hydro-entangler 66 shown in Fig. 8 and described above. The belt 60 terminates after the entangler and the collated and combined mat is laid onto a drum dryer 102 which extracts the water previously applied in the water-jet entangler as the mat structure passes around the periphery of the drum dryer.

Downstream of the dryer 102, the mat again passes between a pair of hot rolls 106 which act to 35 further calender the mat and also to melt and activate the polyester fibers to provide a bonding action. A needler or perforator 108 has a head 110 which supports a plurality of parallel, relatively closely-spaced

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needles 112 (Fig. 15) located downstream of the hot rolls 106. The head 110 is reciprocated to sequentially direct the needles 115 through the mat to form an array of perforations. The array includes perforations spaced both longitudinal and transversely so the series of needles across the width of the mat are punched through the mat as the mat moves forwardly to provide the required number of spaced perforations thus increasing the porous nature of the mat to allow penetration of resin to bond through the mat into the various components of the mat. From 1 to 5000 holes per square inch may be formed in the mat using perforator 108, but about 80 holes per square inch formed by #14 needle size is preferred in a rectangular grid pattern. The needler 108 may be of conventional design which functions at a rate of approximately 20 cycles or reciprocations per second. The holes may be round or polygonal and generally are of a diameter what may be characterized as pin holes. The hole pattern may be random, square, rectangular, close-packed-hexagonal, or similar configurations.

A PVA binder, or an equivalent powdered, solvent, thermal or aqueous based thermoplastic binder is applied to the mat 18 by dispenser 113.

Following perforation of the mat and application of the binder, it is slit by slitter 114 into a plurality of tapes or bands of the required width for use in the subsequent pultrusion process. Each band is then packaged in a suitable manner for example by winding onto a roll so the roll can be transferred to the supply section of the pultrusion process as described hereinbefore.

The mat formation may also be carried out on-line with the pultrusion process so as to avoid the winding and supply steps although in general this is unlikely to be practical in many circumstances due to the different speeds of the processing lines.

The transverse speed at which supply heads 86 and 92 lay down the diagonally-oriented glass rovings 42 and 38 may be adjusted with respect to the velocity of belt 60 to vary the angularity of the glass rovings across the width of the mat on belt 60 from the preferred angularity of about $\pm 45^\circ$ to angles within the range of about $\pm 20^\circ$ to about 70° , and desirably about $\pm 30^\circ$ to 60° with respect to the longitudinal length of the mat, as illustrated in Figs. 13 and 14.

When diagonal glass rovings 38 and 42 are laid down at 70° angles with respect to the longitudinal length of the mat, as shown in Figs. 13 and 14, in many instances the longitudinal rovings 28 may be omitted in that the diagonal rovings provide adequate dimensional stability in the direction of pull to prevent canting, or distortion of the reinforcing mat 18b while passing through pultrusion die 52.

In another alternate embodiment of this invention, the diagonal glass rovings 38 and 42 may be replaced with additional quantities of the transverse glass rovings 32 making up reinforcement layer 34 so that the resultant strength of the fibers in the finished pultruded part lies primarily or generally in the transverse direction.

In the alternate embodiment of the pre-mat before the addition of the batting layer as depicted in Figs. 9-11, two longitudinally-extending glass fiber roving layers 144 and 146 are provided on opposite sides of centrally-located, substantially larger glass fiber rovings in transverse layer 148. Two oppositely-

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diagonal glass fiber roving layers 150 and 152 are positioned against the face of longitudinal layer 144 opposite transverse layer 148. The glass fiber roving layers 150 and 152 are preferably oriented in opposite diagonal directions at about 45° with respect to the longitudinal length of the mat.

- Figure 12 illustrates another embodiment similar to the Fig. 11 embodiment except in this instance, a batting mat layer 154 is positioned on top of the diagonal glass fiber roving layer 150. In this figure, relatively short fibers of the batting mat layer are schematically shown as being entangled with the glass fiber layers 144-152, inclusive.

EXAMPLE 1-Thermally Bonded

- The mat, in a resin matrix, provides the high transverse strength on the surface of the exterior or interior of a pultruded part such as a sash stile or rail, or a pultruded frame head, sill, or jamb, or other products outside the fenestration industry. The cross-section of the pultrusion profile consists of a matrix of thermosetting resin with longitudinal- and/or other-rovings in the middle of the profile thickness, and the mat on the outside surfaces (interior surface in the case of a hollow profile). The mat portion of the laminate is about 0.010" thick, the longitudinal-roving area is about 0.030" thick, and the opposite mat is also about 0.010" thick. The longitudinal-roving-fibers are oriented in the 0° direction. These longitudinal-fibers are mostly 675-yield (yards per pound) fiberglass rovings.

A construction of a reinforcement mat, with the longitudinal direction (e.g. the continuous direction) designated as the 0-0° direction in the plane of the mat, comprised of:

- a first layer of a plurality of 1800-yield fiberglass fibers rovings, substantially in the transverse, or 90° direction in the plane of the mat set at 10 courses per inch;
- a second layer of a plurality of an amide, polyester or reactive sheathed fiber glass bundles spaced 4 per inch, in the +/- 45° direction in the plane of the mat, thermally bonded to the transverse fiberglass;
- a third layer of a plurality of an amide, polyester or reactive sheathed fiber glass bundles spaced 4 per inch, in the 0° direction in the plane of the mat, thermally bonded to the transverse fiberglass;
- a fourth layer of a plurality of polyester fibers that have at least portions thereof which extend in the thickness direction through the third, second and/or first layer to effect a connection there-between, with a pre-entangled weight of 32 grams per square meter;
- with holes primarily between the transverse 1800-yield roving, like sieve-holes in the through-thickness direction, with the holes numbering eighty per square-inch in a rectangular grid pattern;
- with a PVA-based binder to adhere the multiple layers and/or the interstices within a given layer;
- with the entire mat thickness (slightly compressed during thickness measurement) at approximately 0.010-inches;
- and a back-side with alternately-spaced 0° fibers as a third layer of a plurality of an amide, polyester or reactive sheathed fiber glass bundles spaced 4 per inch, in the 0° direction in the plane of the mat, thermally bonded to the transverse fiberglass.

EXAMPLE 2--Polyester Stitched

The mat, in a resin matrix, provides the high transverse strength on the surface of the exterior or interior of a pultruded sash stile or rail, or a pultruded frame head, sill, or jamb. The cross-section of the pultrusion profile consists of a matrix of thermosetting resin with longitudinal- and/or other-rovings in the middle of the profile thickness, and the mat on the outside surfaces (interior surface in the case of a hollow profile). The mat portion of the laminate is about 0.010" thick, the longitudinal-roving area is about 0.030" thick, and the opposite mat is also about 0.010" thick. The longitudinal-roving-fibers are oriented in the 0° direction. These longitudinal-fibers are mostly 675-yield (yards per pound) fiberglass rovings. A construction of a reinforcement mat, with the longitudinal direction (e.g. the continuous direction) designated as the 0° direction in the plane of the mat, comprised of:

- a first layer of a plurality of 1800-yield fiberglass fibers rovings, substantially in the transverse, or 90° direction in the plane of the mat set at 10 courses per inch;
- a second layer of a plurality of 6-denier polyester thread spaced 6 per inch, in the +45° direction in the plane of the mat, stitched to the transverse fiberglass;
- a third layer of a plurality of a 6-denier polyester thread spaced 6 per inch, in the 0° direction in the plane of the mat, stitched to the transverse fiberglass;
- a fourth layer of a plurality of 6-denier fibers that have at least portions thereof which extend in the thickness direction through the third, second and/or first layer to effect a connection there-between, with a pre-entangled weight of 32 grams per square meter;
- with holes primarily between the transverse 1800-yield roving, like sieve-holes in the through-thickness direction, with the holes numbering eighty per square-inch in a rectangular grid pattern;
- with a PVA-based binder to adhere the multiple layers and/or the interstices within a given layer;
- with the entire mat thickness (slightly compressed during thickness measurement) at approximately 0.010-inches;
- and a back-side with alternately-spaced 0° fibers as a third layer of a plurality of a 6-denier polyester thread spaced 6 per inch, in the 0° direction in the plane of the mat, and stitched to the transverse fiberglass.

EXAMPLE 3--Fiberglass Stitched

- The mat, in a resin matrix, provides the high transverse strength on the surface of the exterior or interior of a pultruded sash stile or rail, or a pultruded frame head, sill, or jamb. The cross-section of the pultrusion profile consists of a matrix of thermosetting resin with longitudinal- and/or other-rovings in the middle of the profile thickness, and the mat on the outside surfaces (interior surface in the case of a hollow profile). The mat portion of the laminate is about 0.010" thick, the longitudinal-roving area is about 0.030" thick, and the opposite mat is also about 0.010" thick. The longitudinal-roving-fibers are oriented in the 0° direction. These longitudinal-fibers are mostly 675-yield (yards per pound) fiberglass rovings.

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A construction of a reinforcement mat, with the longitudinal direction (e.g. the continuous direction) designated as the 0° direction in the plane of the mat, comprised of:

a first layer of a plurality of 1800-yield fiberglass fibers rovings, substantially in the transverse, or 90° direction in the plane of the mat set at 10 courses per inch;

5 a second layer of a plurality of fiberglass fiber bundles spaced 4 per inch, in the +45° direction in the plane of the mat, stitched to the transverse fiberglass;

a third layer of a plurality of a 6-denier polyester thread spaced 4 per inch, in the 0° direction in the plane of the mat, stitched to the transverse fiberglass;

10 a fourth layer of a plurality of polyester fibers that have at least portions thereof which extend in the thickness direction through the third, second and/or first layer to effect a connection there-between, with a pre-entangled weight of 32 grams per square meter;

with holes primarily between the transverse 1800-yield roving, like sieve-holes in the through-thickness direction, with the holes numbering eighty per square-inch in a rectangular grid pattern;

with a PVA-based binder to adhere the multiple layers and/or the interstices within a given layer;

15 with the entire mat thickness (slightly compressed during thickness measurement) at approximately 0.010-inches;

and a back-side with alternately-spaced 0° fibers as a third layer of a plurality of a fiberglass bundles spaced 4 per inch, in the 0° direction in the plane of the mat, and stitched to the transverse fiberglass.

20 Since various modifications can be made in our invention as herein above described, and many apparently widely different embodiments of same made within the spirit and scope of the claims without departing from such spirit and scope, it is intended that all matter contained in the accompanying specification shall be interpreted as illustrative only and not in a limiting sense.

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WE CLAIM:

1. A method of preparing a mat for use as reinforcement for a resin composition to be used in forming an elongated, pultruded part of constant transverse cross-section using a pultrusion die, said
5 method comprising:
 providing a pull layer of continuous, generally longitudinally-arranged pulling fibers which
 provide strength to the mat longitudinally thereof in the pull direction of the mat during
 pultrusion of the part;
 providing a reinforcement layer of angular mat fibers in association with the pulling fiber layer
10 and oriented in a direction at an angle with respect to the longitudinal pull direction of the
 mat to provide stiffness to the mat during pultrusion of the part;
 providing a quantity of an uncured synthetic resin in association with at least certain of the fibers,
 said resin being capable of decreasing in viscosity sufficient to diffuse through the mat
 layers and of then undergoing curing as the mat and resin are pulled through the extrusion
15 die; and
 providing fibers, at least a portion of which extend through the thickness of the mat layers and
 interconnect the fibers of the layers to increase the integrity of the mat during pultrusion
 of the part and curing of the resin.
- 20 2. The method of claim 1 wherein the fibers, at least a portion of which extend through the
 thickness of the mat layers and which extend through and interconnect the mat layers, are entangling fibers.
3. The method of claim 2 wherein the entangling fibers have a bending resistance less than
 that of the fibers of the pull layer and the angular mat fibers of the reinforcement layer.
- 25 4. The method of claim 3 wherein the entangling fibers are formed of a cut-staple material.
5. The method of claim 2 wherein the fibers of the pull layer are formed of glass and the
30 entangling fibers are of a synthetic resin polymer.
6. The method of claim 2 wherein at least certain of the entangling fibers are heat bonded to
 the fibers of the pull layer and the angular mat fibers of the reinforcement layer.

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7. The method of claim 2 wherein the entangling fibers include at least certain fibers which have a lower melting temperature than other entangling fibers such that the lower melting fibers are bonded to the pull layer fibers and the angular mat fibers of the reinforcement layer during pulling of the pultruded part through the pultrusion die.

5

8. The method of claim 2 wherein said entangling fibers are B-stage thermoset or thermoplastic fibers.

9. The method of claim 8 wherein said entangling fibers are a polyester terephthalate.

10

10. The method of claim 2 which includes applying forces to the mat layers which deflect at least certain of the fibers of said reinforcement layer to provide said entangling fibers.

11. The method of claim 10 which includes applying forces generally normal to the reinforcement layer for deflecting fibers thereof to produce said entangling fibers.

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12. The method of claim 10 which includes applying water-jets in a direction generally normal to the reinforcement layer to produce said entangling fibers.

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13. The method of claim 2 which includes subjecting the fibers of the reinforcement layer to hydraulic forces from a hydro-entangler to produce said entangling fibers.

14. The method of claim 13 which includes subjecting the fibers of the reinforcement layer to hydraulic forces within the range of about 600 psi to about 1200 psi to produce said entangling fibers.

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15. The method of claim 1 wherein the angular mat fibers of the reinforcement layer are attached to the fibers of the pull layer by heat bonding thereof.

16. The method of claim 1 which includes providing a first portion of reinforcement fibers which extend diagonally from one side of the mat to the other side and a second portion of reinforcement fibers which extend diagonally from said other side to said one side.

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17. The method of claim 16 wherein the first and second portions of said reinforcement fibers each lie along respective straight lines at a common angle.

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18. The method of claim 16 wherein the angle of the first and second portions of the reinforcement fibers is essentially the same.

19. The method of claim 1 which includes providing reinforcement fibers which extend at an
5 angle of from about 30° to about 90° with respect to the longitudinal pull direction of the mat.

20. The method of claim 19 which includes providing reinforcement fibers which extend at an angle of from about 20° to about 90° relative to the direction of the pull of the mat and in an opposed direction from about 20° to about 90° with respect to the longitudinal pull direction of the mat.

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21. The method of claim 19 which includes providing reinforcement fibers which extend at an angle of about 70° relative to the direction of the pull of the mat and in an opposed direction of about 70° with respect to the longitudinal pull direction of the mat.

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22. The method of claim 19 which includes providing reinforcement fibers which extend at an angle of about 45° with respect to the longitudinal pull direction of the mat.

23. The method of claim 19 which includes providing reinforcement fibers which extend at an angle of about 90° with respect to the longitudinal pull direction of the mat.

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24. The method of claim 19 which includes providing reinforcement fibers which extend at an angle of about 45° with respect to the longitudinal pull direction of the mat, and reinforcement fibers which extend in a direction of about 90° with respect to the longitudinal pull direction of the mat.

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25. The method of claim 1 which includes providing pull layer fibers of glass, and reinforcement layer fibers of a synthetic resin material.

26. The method of claim 25 wherein said synthetic resin material is a thermosetting resin.

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27. The method of claim 26 wherein said thermosetting resin is a thermosetting polyester.

28. The method of claim 25 wherein said reinforcement layer fibers are in the form of random-oriented fibers presenting a flexible, relatively thin batting.

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29. The method of claim 28 wherein is provided stitching interconnecting the batting and the mat layers for substantially maintaining the integrity and orientation of the mat fibers with respect to the batting fibers.

5 30. The method of claim 29 wherein is provided stitching which extends longitudinally and at an angle with respect to the mat layers and flexible batting layer.

31. The method of claim 29 wherein said stitching comprises a polyester thread.

10 32. The method of claim 1 wherein said uncured resin is a thermosetting resin.

33. The method of claim 1 wherein said uncured resin is a polyvinyl acetate-based binder.

34. The method of claim 1 wherein said quantity of synthetic resin comprises a synthetic
15 resin coating on at least certain of the fibers of the reinforcement layer.

35. The method of claim 34 wherein said synthetic resin coating is a thermosetting resin selected from the group consisting of amid and polyester resins capable of undergoing melting and diffusion through the mat layers as the mat is pulled through the pultrusion die along with said resin
20 composition.

36. The method of claim 1 wherein is provided an array of spaced holes extending through at least certain of the layers of the mat.

25 37. The method of claim 36 wherein said holes are located primarily between said angular mat fibers.

38. The method of claim 36 wherein said holes number from 1 to 5,000 per square inch.

30 39. The method of claim 36 wherein said holes are selected from the group of round, polygonal or pin holes.

40. The method of claim 39 wherein said holes are arranged in pattern pattern orientations selected from the group of relatively close-packed random, circular, square, rectangular, or hexagonal.

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41. The method of claim 1 wherein the fibers of said pull layer comprise a first layer oriented
5 at about 0° with respect to the pull direction of the mat, the angular mat fibers in the reinforcement layer
comprise a second layer oriented at about 90° with respect to the pull direction of the mat, a third
reinforcement layer being provided having angular mat fibers oriented at about $\pm 45^\circ$ with respect to the
pull direction of the mat, said fibers, at least a portion of which extend through the thickness of the mat
layers, comprising a fourth layer of synthetic resin fibers.

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42. The method of claim 41 wherein said fourth layer comprises polyester fibers.

43. The method of claim 41 wherein said quantity of synthetic resin in association with at
least certain of the fibers comprises a polyvinyl acetate-based binder.

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44. The method of claim 41 wherein said first and second layers are thermally bonded
together by said quantity of synthetic resin associated with at least certain of the fibers, during passage of
the pultruded part through a pultrusion die.

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45. The method of claim 1 wherein said quantity of synthetic resin in association with at least
certain of the fibers is selected from the group consisting of a powder, solvent, thermal or aqueous-based
thermoplastic binder.

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46. The method of claim 1 where the entire mat thickness is no more than about .020 in.

47. The method of claim 1 wherein the edges of the mat are folded over to form a hem
defining added longitudinal fibers to reinforce the edges of the mat.

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48. A mat prepared in accordance with the method of claim 2.

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49. A method of preparing a mat for use as reinforcement for a resin composition to be used in forming an elongated, pultruded part of constant transverse cross-section using a pultrusion die, said method comprising:

- 5 providing a pull layer of continuous, generally longitudinally-arranged pulling fibers to provide strength to the mat longitudinally thereof in the pull direction of the mat during pultrusion of the part;
- providing a reinforcement layer of angular mat fibers in association with the pulling fiber layer and oriented in a direction at an angle with respect to the longitudinal pull direction of the mat to provide stiffness to the mat during pultrusion of the part;
- 10 stitching the pull layer and the reinforcement layer together to provide a mat in which the layers are interconnected by lines of stitching; and
- providing fibers, at least a portion of which extend through the thickness of the mat layers and interconnect the fibers of the layers to increase the integrity of the mat during pultrusion of the part and curing of the resin composition.

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50. The method of claim 49 which includes providing a second reinforcement layer having randomly disposed fibers, and stitching the angular reinforcement layer and the layer of randomly oriented fibers together to preclude significant displacement of one layer with respect to the other layer.

20

51. The method of claim 50 wherein said stitching is a thermosetting polyester thread.

52. The method of claim 49 wherein is provided a series of spaced holes extending through the layers of the mat.

25

53. A mat prepared in accordance with the method of claim 49.

54. A method of preparing a mat for use as reinforcement for a resin composition to be used in forming an elongated, pultruded part of constant transverse cross-section using a pultrusion die, said method comprising:

- 30 providing a pull layer of continuous, generally longitudinally-arranged pulling fibers to provide strength to the mat longitudinally thereof in the pull direction of the mat during pultrusion of the part;
- providing a reinforcement layer of angular mat fibers in association with the pulling fiber layer and oriented in a direction at an angle with respect to the longitudinal pull direction of the mat to provide stiffness to the mat during pultrusion of the part;
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stitching the pull layer and the reinforcement layer together to provide a mat in which the layers are all interconnected by lines of stitching; and
providing a quantity of an uncured synthetic resin in association with at least certain of the fibers, said resin being capable of decreasing in viscosity sufficient to diffuse through the mat layers and of then undergoing curing as the mat and resin are pulled through the extrusion die.

55. The method of claim 54 wherein said angular mat fibers are oriented transversely of the direction of pull of the mat during pultrusion of the part.

56. The method of claim 55 wherein the angular mat fibers of the reinforcement layer make up a greater proportion of the mat than the fibers in the pulling layer.

57. A mat prepared in accordance with the method of claim 54.

58. A method of preparing a mat for use as reinforcement for a resin composition to be used in forming an elongated, pultruded part of constant transverse cross-section using a pultrusion die, said method comprising:

providing first and second mat layers of continuous fibers, said layers being arranged in opposite, substantially equal angular directions with respect to the pull direction of the mat during pultrusion of the part;

providing a quantity of an uncured synthetic resin in association with at least certain of the fibers, said resin being capable of decreasing in viscosity sufficient to diffuse through the mat layers and of then undergoing curing as the mat and resin are pulled through the extrusion die; and

providing a batting containing fibers at least a portion of which comprise entangling fibers.

59. The method of claim 58 wherein at least a portion of said entangling fibers extend through the thickness of the mat layers and interconnect the fibers of the layers to increase the integrity of the mat during pultrusion of the part and curing of the resin.

60. The method of claim 58 wherein said first and second mat layers are arranged at opposite approximately 70° angles with respect to the pull direction of the mat.

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61. The method of claim 58 wherein is provided stitching interconnecting the batting and the mat layers for substantially maintaining the integrity and orientation of the mat fibers with respect to the batting fibers.

- 5 62. A pultruded part of constant transverse, predetermined cross-sectional shape and formed by a pultrusion die comprising:
- a continuous stretch of elongated glass roving;
 - an elongated reinforcement mat associated with the stretch of glass roving, said reinforcement mat including
 - 10 a first layer of continuous, generally longitudinally-arranged pulling fibers which provides strength to the mat longitudinally thereof;
 - a reinforcement layer of angular mat fibers in association with the pulling fiber layer and oriented in a direction at an angle with respect to the longitudinal pull direction of the mat which provides strength and stiffness to the mat;
 - 15 a batting layer containing fibers, at least a portion of which extend through the thickness of the mat layers and interconnect the fibers of the layers to increase the integrity of the mat during pultrusion of the part;
 - a quantity of a cured synthetic resin diffused through and bonding the mat layers into a monolithic body; and
 - 20 a synthetic resin composition enveloping said mat and the elongated glass roving and configured to present said predetermined desired cross-sectional shape of the part.

25 63. A pultruded part as set forth in claim 62 wherein at least a portion of the fibers of the batting layer which extend through and interconnect the mat layers are entangling fibers.

 64. A pultruded part as set forth in claim 62 wherein the angular mat fibers are disposed at an angle of about 90° with respect to the longitudinal length of the fibers of the first layer.

30 65. A pultruded part as set forth in claim 62 wherein is provided a first set of angular mat fibers which are disposed at an angle of from about 30° to about 90° and a second set of angular mat fibers which are disposed at an angle of -30° to about -90° with respect to the longitudinal length of the fibers of the first layer.

35 66. A pultruded part as set forth in claim 62 wherein is provided a first set of angular mat fibers which are disposed at an angle of + 45° and a second set of angular mat fibers which are disposed at an angle of - 45° with respect to the longitudinal length of the fibers of the first layer.

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67. A pultruded part as set forth in claim 62 wherein the fibers of said first layer include a first body of fibers disposed at an angle of no more than about + 70° with respect to the longitudinal length of the stretch of glass roving, and a second body of fibers disposed at an equal angle of no more than about - 70° with respect to the longitudinal length of the stretch of glass roving.

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68. A pultruded part as set forth in claim 62 wherein is provided a network of polymer stitching joining and interconnecting at least certain layers of the mat.

69. A pultruded part as set forth in claim 62 wherein is provided a series of individual, spaced, generally tubular areas extending through the layers of the mat, said areas being filled with the cured synthetic resin which thereby increases the reinforcement properties of the mat.

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70. A pultruded part as set forth in claim 62 wherein said part is a fenestration component selected from the group of window jambs, sills, heads, sash stiles and sash rails.

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71. A pultruded part as set forth in claim 70 wherein said mat is adjacent the normally outermost surface of said component.

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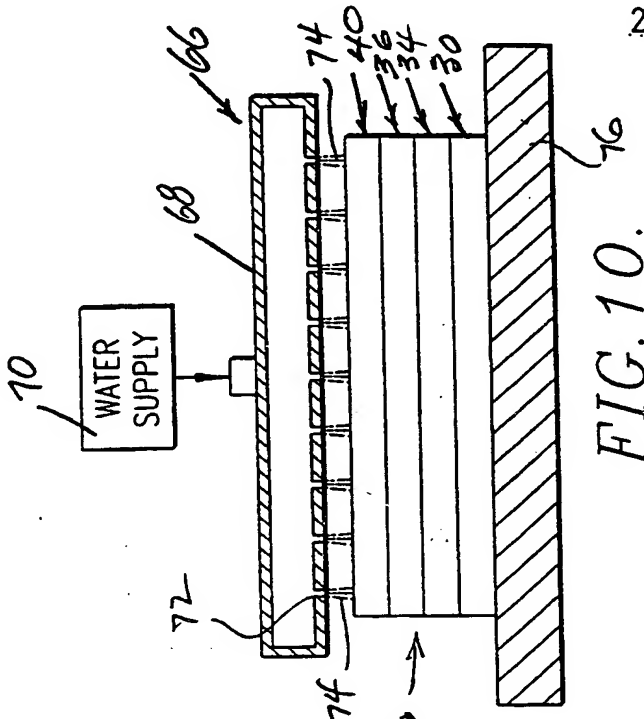


FIG. 10.

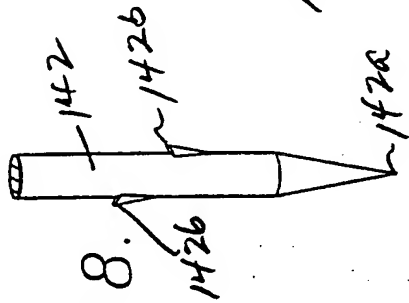


FIG. 18.

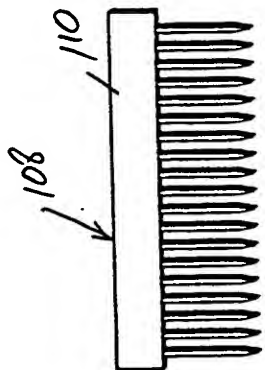


FIG. 17.

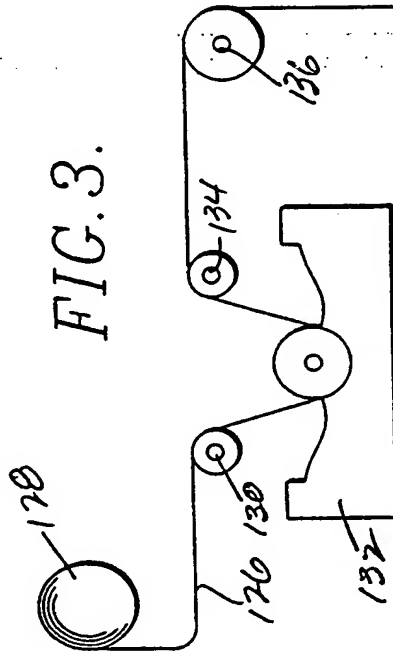
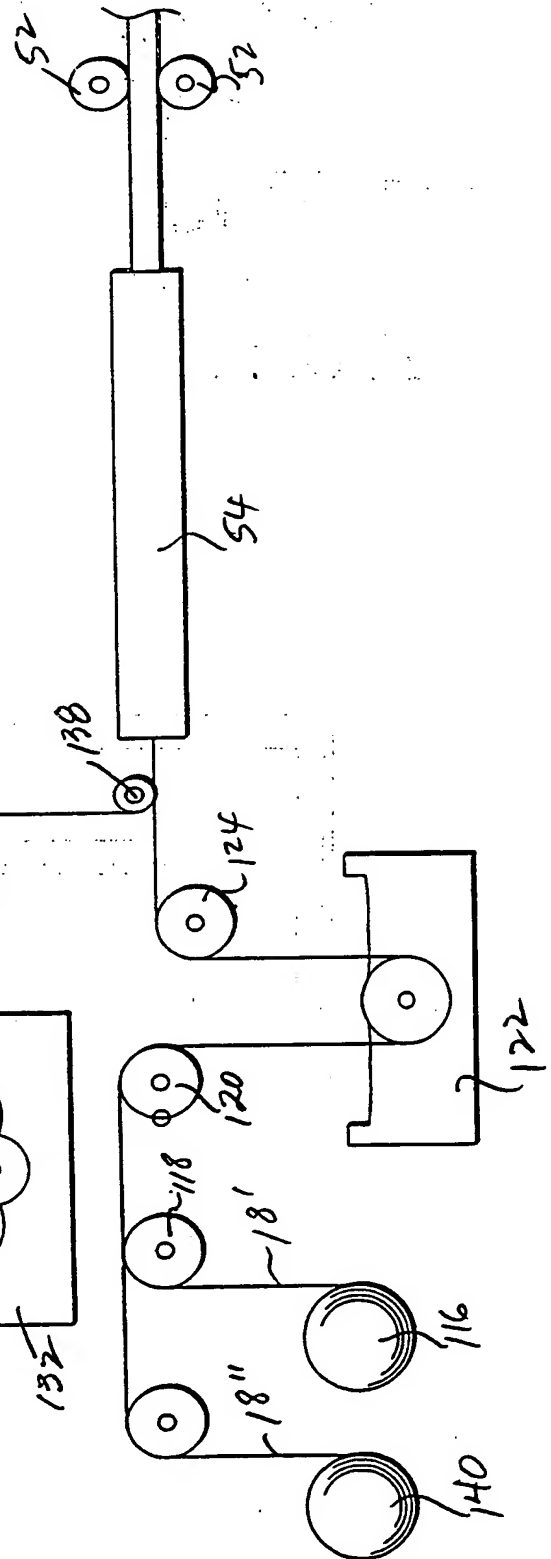
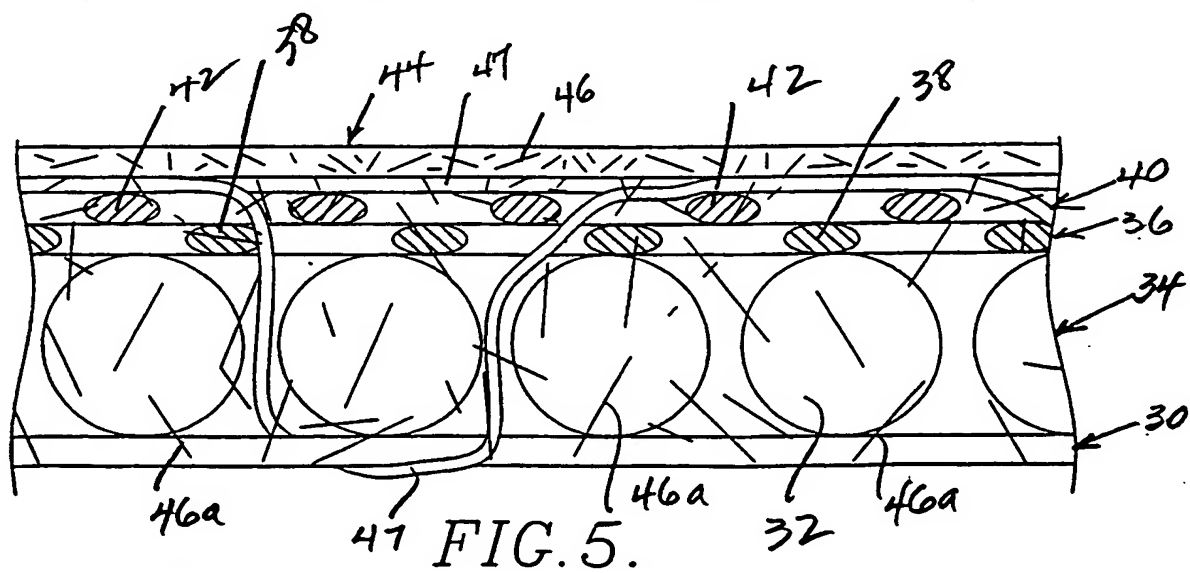
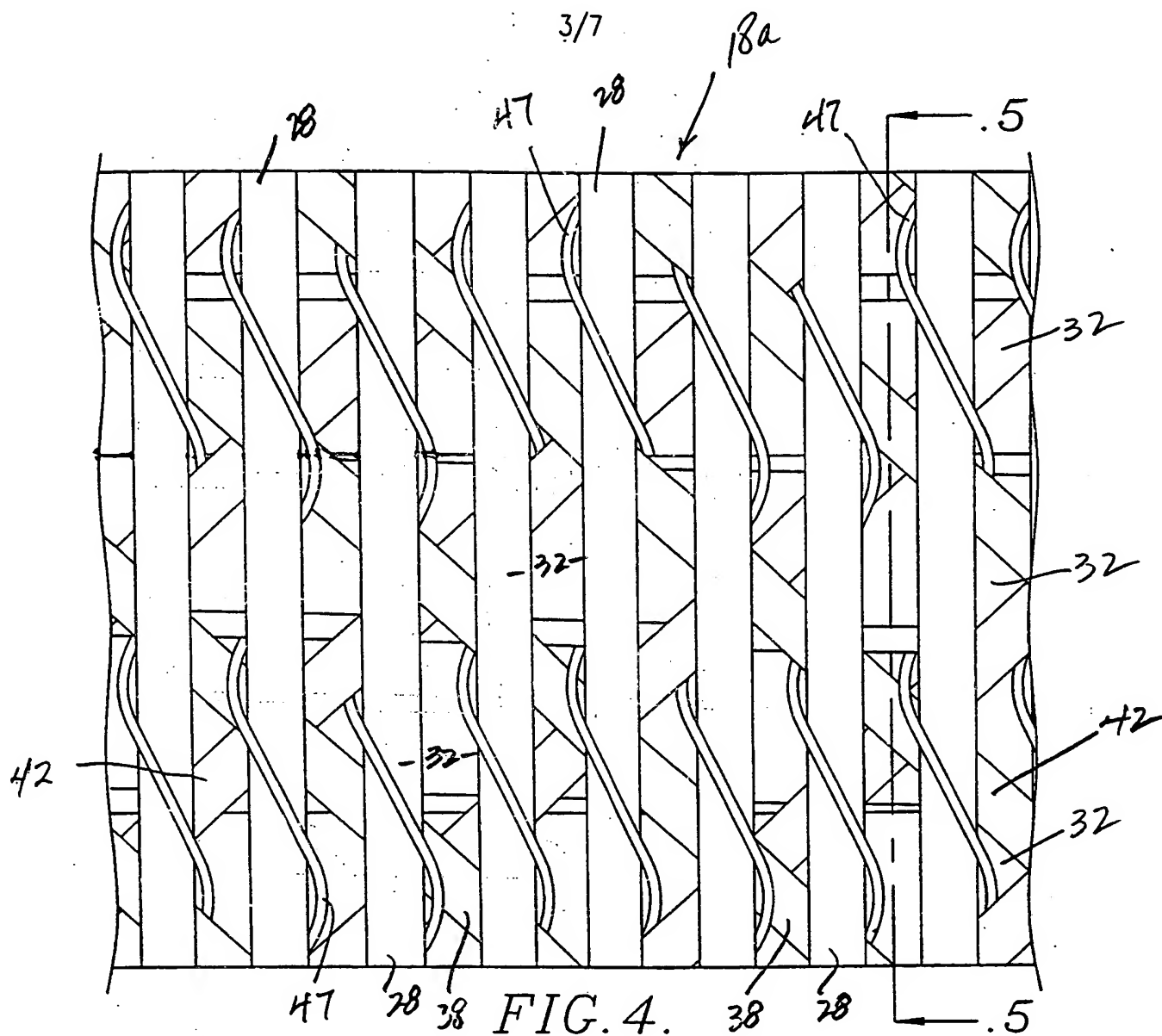
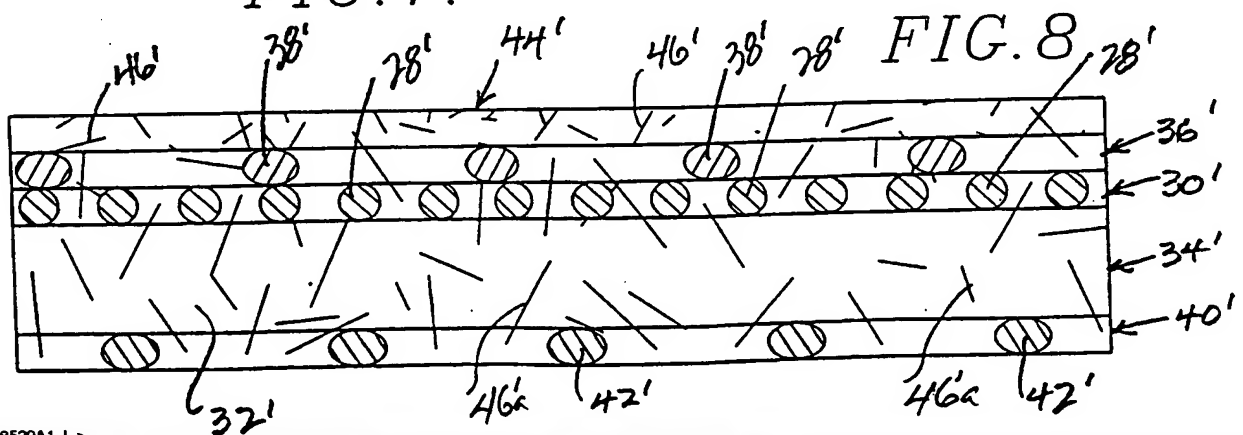
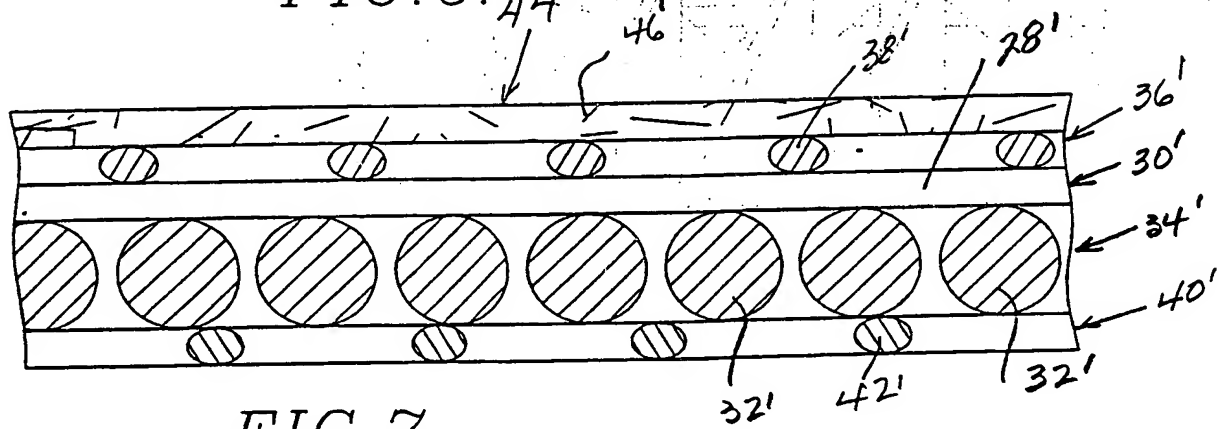
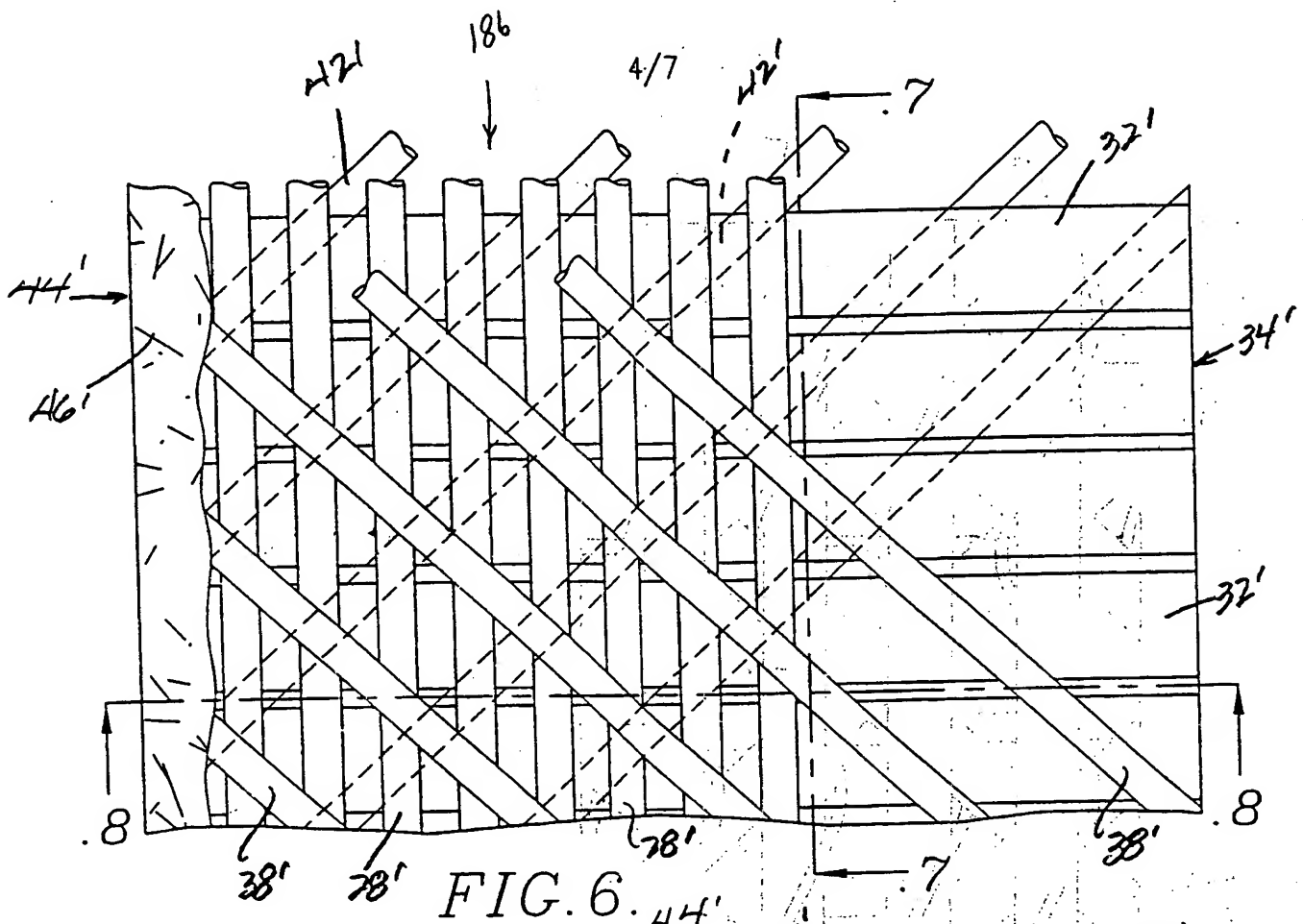


FIG. 3.

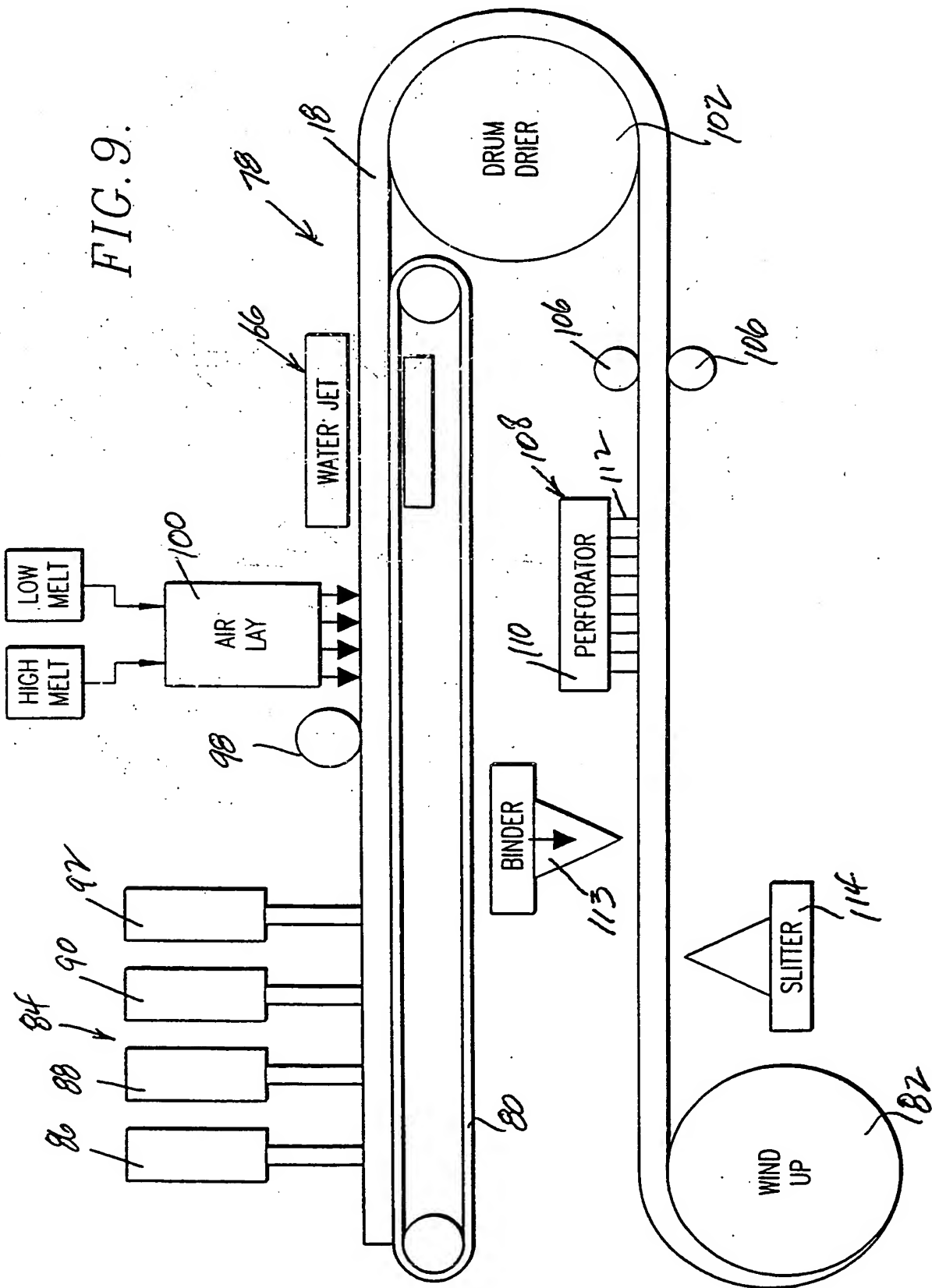






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FIG. 9.



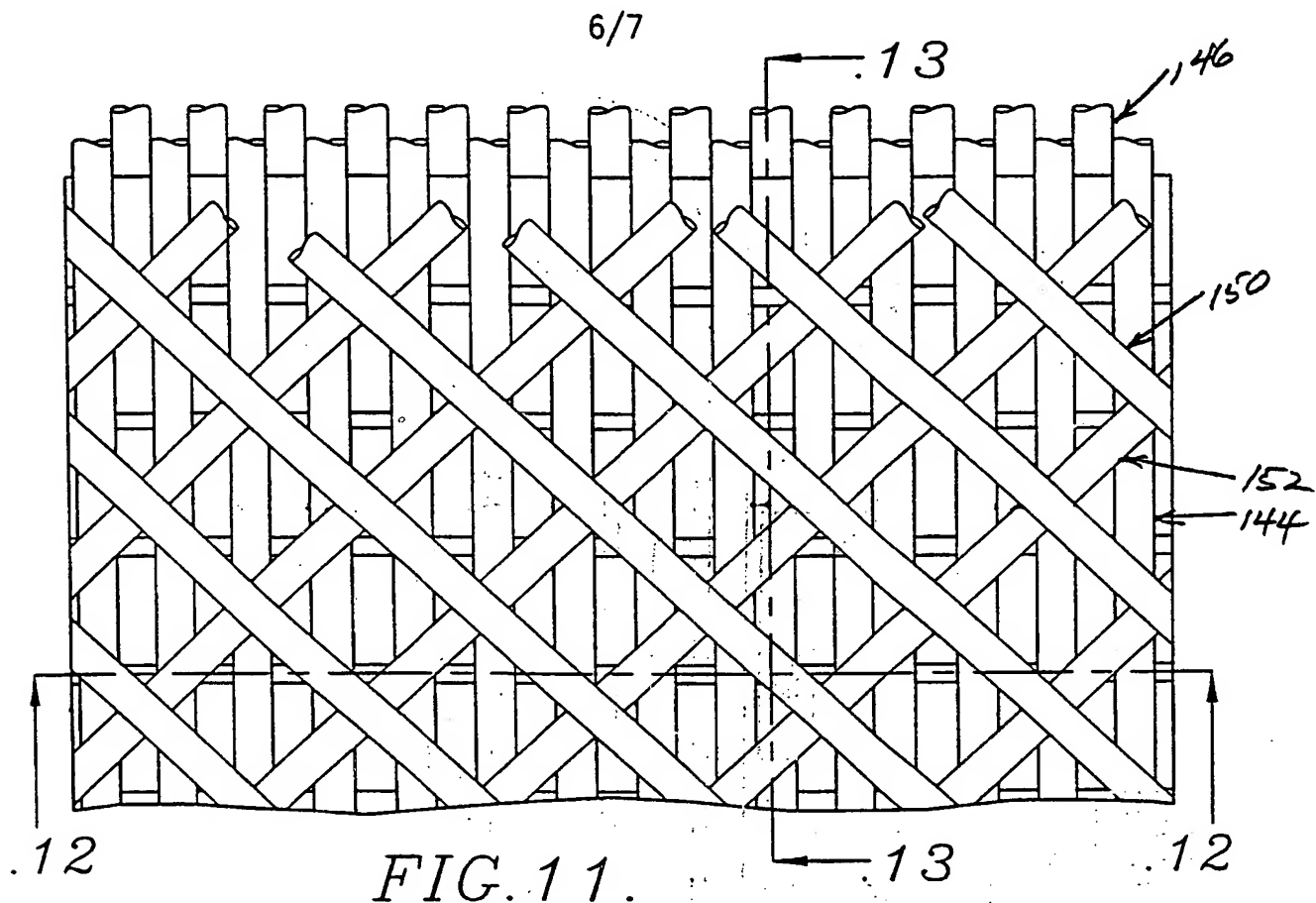


FIG. 12.

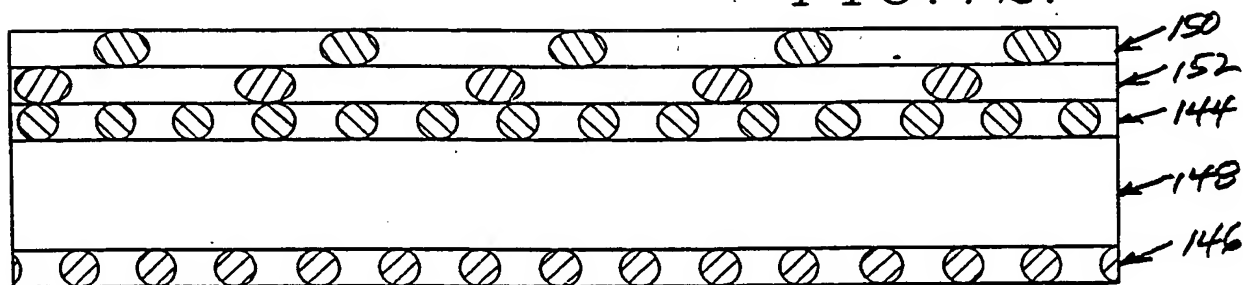
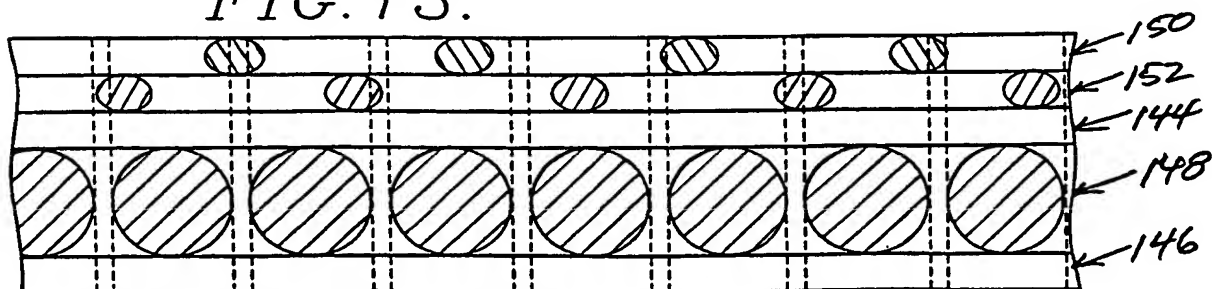


FIG. 13.



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FIG. 14.

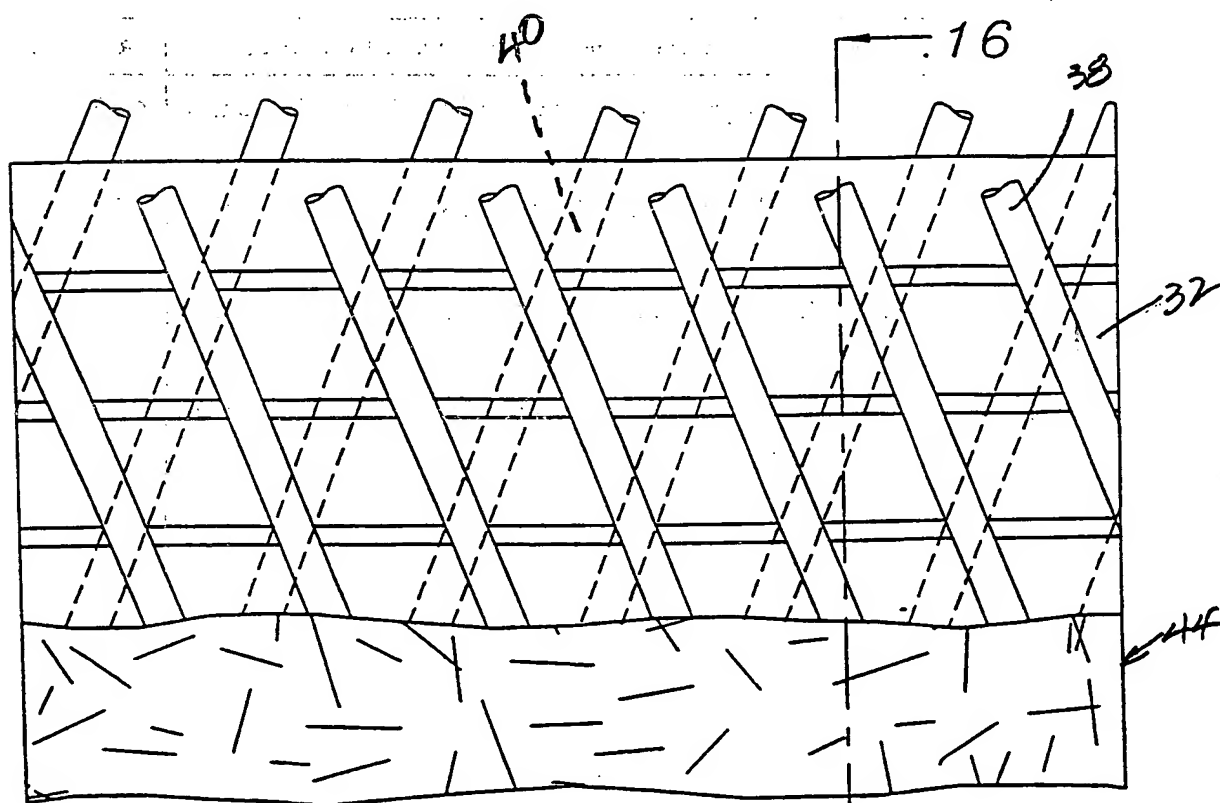
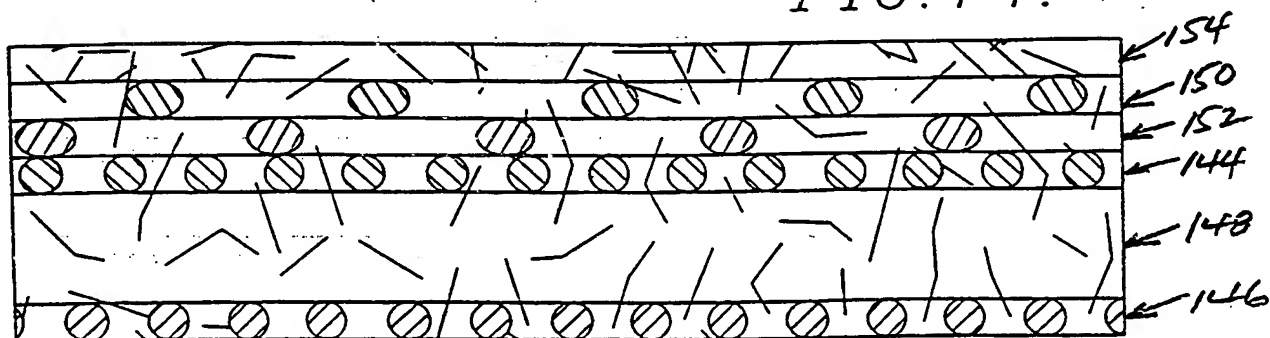
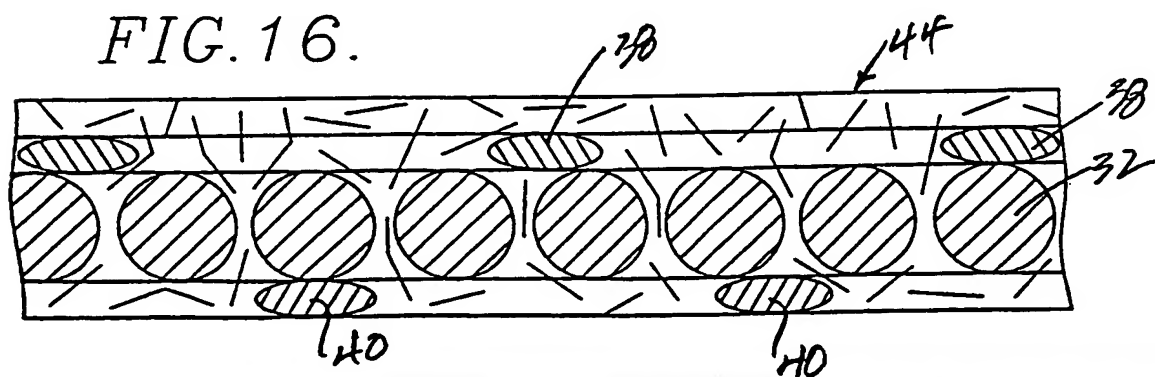


FIG. 15.

FIG. 16.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/40246**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : B29C 70/52

US CL : 156/93, 148, 166, 176-180; 442/366, 367, 381, 387-388, 402

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 156/93, 148, 166, 176-180; 442/366, 367, 381, 387-388, 402

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
noneElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
none**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,055,242 A (VANE) 08 October 1991 (08.10.91), entire document.	49-71
Y	US 4,752,513 A (RAU, ET AL) 21 June 1988 (21.06.88), entire document.	1-71
Y	US 5,908,689 A (DANA ET AL) 01 June 1999 (01.06.99), entire document.	1-48
Y	US 5,910,458 A (BEER, ET AL) 08 June 1999 (08.06.99), entire document.	1-48

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

06 SEPTEMBER 2000

Date of mailing of the international search report

19 SEP 2000

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

JEFF AFTERGUT

Telephone No. (703) 308-0661

PATENT COOPERATION TREATY

*Cite in US case 1.704(d) 2/13/03
PCT or 4/13/03*

From the INTERNATIONAL SEARCHING AUTHORITY

To:

Faegre & Benson LLP
Attn. Schwappach, Karl G.
2200 Norwest Center
90 South Seventh Street
Minneapolis, MN 55402-3901
UNITED STATES OF AMERICA

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT
OR THE DECLARATION

(PCT Rule 44.1)

Amend. Claims Art. 19 due 3/13/03

Date of mailing
(day/month/year)

13/01/2003

Applicant's or agent's file reference

26998-277107

FOR FURTHER ACTION

See paragraphs 1 and 4 below

International application No.

PCT/US 02/32019

International filing date
(day/month/year)

07/10/2002

Applicant

PELLA CORPORATION

1. ☒ The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority



European Patent Office, P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Paul Faux

1. *Journal of the American Medical Association*, 1997; 277: 1033-1036.

^a Values are means ± SD.

[illegible]

Figure 1. The effect of the concentration of the *Agrobacterium* suspension on the transformation efficiency of *Agrobacterium* strains. The concentration of the *Agrobacterium* suspension was 10⁶ cells/ml (A), 10⁷ cells/ml (B), 10⁸ cells/ml (C), and 10⁹ cells/ml (D). The concentration of the *Agrobacterium* suspension was 10⁶ cells/ml (A), 10⁷ cells/ml (B), 10⁸ cells/ml (C), and 10⁹ cells/ml (D). The concentration of the *Agrobacterium* suspension was 10⁶ cells/ml (A), 10⁷ cells/ml (B), 10⁸ cells/ml (C), and 10⁹ cells/ml (D). The concentration of the *Agrobacterium* suspension was 10⁶ cells/ml (A), 10⁷ cells/ml (B), 10⁸ cells/ml (C), and 10⁹ cells/ml (D).

Figure 1. The effect of the number of trials on the number of correct responses. The number of correct responses was significantly higher than the number of incorrect responses for all groups. The number of correct responses was significantly higher than the number of incorrect responses for all groups. The number of correct responses was significantly higher than the number of incorrect responses for all groups.

[illegible]

Figure 1. The effect of the concentration of the *Agrobacterium* suspension on the transformation efficiency of *Agrobacterium* strains.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 26998-277107	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/US 02/ 32019	International filing date (day/month/year) 07/10/2002	(Earliest) Priority Date (day/month/year) 11/12/2001
Applicant PELLA CORPORATION		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

4
☐ . None of the figures.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/32019

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C70/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 78529 A (PELLA CORP) 28 December 2000 (2000-12-28) examples 1-3 -----	1-34

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

G document member of the same patent family

Date of the actual completion of the international search

3 January 2003

Date of mailing of the international search report

13/01/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Dupuis, J-L

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 02/32019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0078529	A	28-12-2000	
		AU 6648500 A	09-01-2001
		EP 1204529 A1	15-05-2002
		WO 0078529 A1	28-12-2000
		US 2002121722 A1	05-09-2002
		US 2002121720 A1	05-09-2002
		US 2002123287 A1	05-09-2002
		US 2002123288 A1	05-09-2002

